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**Assessing comprehension
of spoken language in non-
speaking children with
cerebral palsy: application
of a newly developed
computer-based instrument**



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ABSTRACT

This paper describes the development of an instrument to assess comprehension of spoken language in children with severe cerebral palsy (CP) who cannot speak, and for whom standard language assessment measures are not appropriate due to severe motor impairment.

This instrument, the Computer-Based instrument for Low motor Language Testing (CBiLLT), was administered to 42 children without disabilities (aged 14 months to 60 months) and to 18 children with severe CP (age 19 months to 71 months). Preliminary data showed that the instrument was acceptable to the children. Convergent validity was investigated by correlating C-BiLLT scores with test results on the well-established Reynell Developmental Language Scales (RDLS). Clinical implications and recommendations for future research are discussed.

INTRODUCTION

Cerebral palsy (CP) is described as a group of disorders that is attributed to non-progressive disturbances that occurred in the developing foetal or early infant brain before the first year of life.¹ The classification of CP retains the classical neurological terms for central motor disorders, i.e. spasticity, dyskinesia and ataxia.² Speech and communication impairment can be associated with any type of CP, irrespective of the nature of the central motor disorder in classical neurological terms.³ Yet, the severity of the motor impairment is an important variable in the communication development of children with CP.⁴ The Gross Motor Function Classification System (GMFCS)⁵ is a five-level classification system that emphasizes the concepts inherent in the World Health Organization's International Classification of Functioning, Disability and Health.⁶ The descriptions of functional abilities and limitations are based on self-initiated movements and are explicitly not intended to describe all aspects of the functioning of individual children.⁷ However, the GMFCS levels correlate well with the extent of accompanying impairments, including limitations leading to disabilities in communication, with the most severe impairments in the higher levels (GMFCS IV and V).^{8,9} The most common impairment is dysarthria, but anarthria also occurs. Typically, tetraplegic (four-limb paralysis) children tend to have more complex communication needs.¹⁰

As well as the severity of the motor disorder, disorders in cognitive functioning may also influence the communicative development in children with CP.¹¹ Recent European studies reported that cognitive impairment (intelligence quotient [IQ] below 70) is present in 23-44% of children with CP.⁴ In the general CP population, about 75% of children and adolescents have significant disorder(s) of higher cortical functioning.¹²⁻¹⁴

It is important to distinguish between their expressive and receptive language abilities when assessing communication abilities of children with CP. Verbal comprehension is known to play a pivotal role in early language development¹⁵ and comprehension of words (and later sentences) can develop even when the child is not speaking.¹⁶ Verbal comprehension abilities have been shown to exceed expressive abilities in severely speech impaired children and adolescents.^{17,18} Therefore, assessment of the verbal comprehension abilities in children with complex communication needs is important, because this knowledge will determine how caregivers, teachers, and others interact with them. Moreover, verbal comprehension abilities have important implications for the development of the child's augmentative and alternative communication (AAC) system and/or individual education program.

Unfortunately, common standardized language tests do not seem to meet the test requirements of children with severe CP. These tests require motor action on command, such as manipulating or handling small objects, or pointing at pictures or objects. However, these selection methods can be difficult or even impossible for (young) children with severe motor and/or cognitive impairments. The risk of evaluating a child's inability to carry out a motor task, instead of the child's targeted verbal comprehension abilities has been

criticized earlier^{11,18-21} Further, the use of line drawings as stimuli in tests may be more difficult to recognize by young children and/or children with severe cognitive delays.²²⁻²⁴ There is a risk of under-estimating verbal comprehension abilities which may lead to under-stimulation and even social deprivation, and this in turn, may have negative effects on the child's emotional well-being.²⁵ Therefore, verbal comprehension should be evaluated as early as possible. Instruments used to assess verbal comprehension abilities in children with complex communication needs and CP are scarce, and new assessment tools to reliably assess receptive language abilities are needed.²⁶

The scarcity of test instruments prompted the current study, with the goal of developing and testing the validity, feasibility, and reliability (American Psychological Association, 1986) of a computer-based diagnostic instrument for assessing verbal comprehension abilities in children with complex communication needs and CP, a heterogeneous population. The instrument was named 'Computer-Based instrument for Low motor Language Testing (C-BiLLT). The test was designed to require minimal motor action that can be performed by any body part) and so that the items pertain to verbal comprehension abilities at the sentence level.

The sequencing of the linguistic complexity of items on the test was based on the Dutch version of the 'Comprehension Scale' of the Reynell Developmental Language Scales (RDLS).²⁷ The RDLS has proven to be a well-standardized measure^{28,29} and is one of the most widely used tools for the assessment of sentence level comprehension of spoken language.

We investigated preliminary psychometric qualities and compared differences in performance on the C-BiLLT and on the RDLS in a group of children with complex communication needs and CP as well as in a group of children without disabilities.

METHODS

The Instrument

The C-BiLLT assesses a child's ability to understand spoken language by means of responding to orally presented questions pertaining to visually presented stimuli. This test is primarily based on the Dutch RDLS, but items differ with respect to content, i.e. chosen nouns and verbs refer to objects, persons, animals and actions that are relevant to physically impaired children. The choice of items is motivated by the finding that children with severe CP experience difficulties in exploring the world on their own, foremost due to motor dysfunction.³⁰ Therefore, we chose items that (a) represent objects but are not meant to be manipulated and (b) items that represent actions relevant to children with physical impairments. The C-BiLLT includes an additional section (Section 1, described below) that is not part of the RDLS. Apart Section 1, the 53 items that comprise the test are constructed according to the linguistic hierarchy applied in the first 53 items of the RDLS.

Equipment and set-up: The equipment consists of one Fujitsu-Siemens® 19-inch flat screen with built-in speakers and two special Kompagne® black Jelly bean switches connected to a Cybercom® computer with an intel® Celeron M 320 1.3 GHz processor. The Jelly® bean switches (specifically developed for persons with physical impairments and requiring a very light touch) are used to input responses. Visual representations of the switches are at the bottom of the flat screen (Figure 3.1). The switches and the flat screen are adjustable to any position that favours the child's ability to respond by pressing the switch; or by touching pointing, or using eye gaze. The response is then selected on the computer screen, and visual feedback in the form of a red circle around the switch on the screen is provided. The child remains seated in his/her own (wheel) chair (with or without its own top surface), within a maximum of 20 inches from and facing the flat screen (Figure 3.2).

The photographs of objects, animals and persons were made with a digital Kodak® CX 7530 5.0 mega pixels camera, and edited in Adobe Photoshop, version 2007. A grey slide that fills the entire screen was inserted between items. Only the investigator can initiate the question associated with each question, in order to prevent the subsequent question from being elicited by a participant's unintentional touch or movement.



figure 3.1

Example of an item of the C-BiLLT (Section 2, discriminating between nouns): the child is asked: 'Where is the television?'



figure 3.2

Administration of the C-BiLLT in a 33-month-old boy (GMFCS V, dyskinetic CP)

Test Administration: The C-BiLLT consists of two learning modules and five Sections (grouped into Part I and Part II). The aim of the first learning module was to make the child aware of the association between the two actual input switches on the top surface, the two visual representations of the input switches on the computer screen, and the two stimuli of choice. The child's pushing or grasping the input switches was encouraged by positive feedback of three interactive slides presenting respectively an ascending balloon, a bouncing ball and,

hiding an appealing cartoon figure. Instruction: Sitting next to the child, the investigator says: *Watch me. I am pushing this switch and then I see the balloon ascending. Do you see?, Now, you try! Do the same as I did.* This instruction was repeated with the bouncing ball and the cartoon figure. To learn the child the association between the left and right switch on the top surface and their left and right presentation on the computer screen, two slides were introduced. The first slide portrays respectively a fish and a balloon, and the second slide a flower and a hand. Instruction: *Watch me. I am pushing this switch (push left) to select the flower (the investigator points to the left image and the left switch on the screen and shows the red circle around the switch). And now I am pushing this switch (push right) to select the hand (the investigator points to the right image). Now you try! Please select the hand.* The investigator offers the child ample opportunity to respond. The learning phase is considered successfully completed when the child shows understanding of the operation of the input switches, and of the association with the stimuli presented on the screen.

The aim of the second learning module was to teach the method of linear scanning. A practice slide displayed four images. The investigator says to the child: *See, there is a red square around this picture*, and waits for an affirmative reaction of any kind. The child is instructed to operate the switch in order to linearly display a red square around the four images. The child determines his/her own “dwell time” because the square around the image can only be moved to the next image by operating the input switch. One practice slide is used to master the principle of linear scanning. The investigator says: *See how the square moves from one image to the other as I push it.* The investigator points to the switch and at the square as it moves along the images. Instruction: *Now you try! Do the same as I did!* The investigator offers the child ample opportunity to respond. In case of success, the investigator points at one of the images and says: *Please make the square stop at this image!* Again, the investigator offers the child ample opportunity to respond. This last procedure is repeated until the child performs three consecutive responses that demonstrate an understanding of linear scanning.

Part I of the C-BiLLT consists of four Sections. The child is asked to select one of two digital photographs on a computer monitor (see Figure 3.1) and responds by pressing one of two matching input switches or by touching, pointing to, or using eyegaze to indicate the chosen response on the computer screen.

In *Section 1*, sound recognition, 10 pairs of pictures of animals, objects and persons are presented in random order. Each pair is accompanied by a sound bite with a duration of 30 seconds that matches the target stimulus (such as a dog barking, a baby crying, or the siren of a police car). The investigator asks: *What do you hear?* and offers the child ample opportunity to respond.

In *Section 2*, noun recognition, 10 pairs of pictures of objects (nouns) are presented in random order. The investigator asks: *Where is the ... ?* (e.g. car, doll spoon) and offers the child ample opportunity to respond.

In *Section 3*, verb recognition, 10 pairs of pictures of actions (verbs) are presented in random order. The investigator asks: *Who is?* (e.g. eating, sleeping, playing), and offers the child ample opportunity to respond.

In order to counterbalance the 50% chance of a correct response in Sections 1 through 3, parallel versions were implemented consisting of the same 10 items in fixed random pairs, but in different combinations and in different orders.

In *Section 4*, person, animal, object recognition, the same animals, objects and people as in Section 1 are used but in different combinations and without sound. The investigator asks the child: *Where is the?* (e.g. baby, dog, police car) and offers the child ample opportunity to respond.

Part II of the C-BiLLT is comprised of *Section 5*, that is presented only to those aged 24 months and older, or to those who were successful with at least 16 of the 30 items in Sections 2, 3 and 4. The child is asked to select one of four digital photographs in a 2 X 2 matrix on the computer monitor (see Figure 3.3). In this section 23 complex sentences, each with four response options are presented in a 2x2 matrix (Figure 3.3). The items are verbs, prepositions, and longer and linguistically more complex sentences (e.g. the dog lies in the basket).



figure 3.3

Example of an item of the scanning section (5). The child is asked: 'Can you show me?... the dog lies in the basket'.

The child selects the desired response using linear scanning with one input switch or by touching, pointing to, or using eyegaze to indicate the chosen response on the computer screen.

Scoring: The items of Section 1 (sound recognition) do not relate to verbal comprehension and are scored and evaluated separately from the other Sections (see Table 3.1). One point is scored for every item that is correctly identified in both the original and in the parallel version of Sections 2 and 3. In Sections 4 and 5, one point is scored for every item answered correctly. The total score is the sum of the scores of Sections 2 through 5, with a maximum score of 53.

Table 3.1 Child Characteristics, Communication Modes, Scores on Sections 1-5 and Total Score on the C-BiLLT, and Total RDLS Score for Each Participant with Disabilities.

Participant	Characteristics			Communication Modes			C-BiLLT Section					RDLS	
	Age	Gender	GMFCS	CP type	Verbal prod	Response mode	1	2	3	4	5	Total (2-5)	Total
1	19	M	5	Spastic	Absent	Eye-gaze	5	6	4	0	0	10	3
2	20	M	5	Spastic	Absent	Eye-gaze	0	0	0	0	0	0	0
3	27	M	5	Spastic	Absent	Eye-gaze + switch with hand	5	5	3	6	0	14	3
4	29	F	5	Dyskinetic	Absent	Switch with arm	10	10	10	10	42	42	23
5	30	F	4	Spastic	Absent	Hand on screen	3	9	7	7	6	29	32
6	31	M	4	Spastic	Absent	Hand on screen	1	5	3	5	1	14	13
7	33	M	5	Mixed	Absent	Eye-gaze + switch with hand	4	6	4	2	4	16	3
8	35	M	5	Spastic	Absent	Eye-gaze	7	6	9	6	1	22	8
9	36	F	4	Spastic	Present	Hand on screen	0	5	0	0	0	5	3
10	37	F	5	Spastic	Absent	Eye-gaze	5	7	3	0	0	10	5
11	43	F	4	Spastic	Present	Switch with hand	1	10	8	6	6	30	20
12	43	F	4	Dyskinetic	Absent	Hand on screen	6	8	4	0	7	19	7
13	46	M	5	Dyskinetic	Absent	Switch with hand	10	10	10	10	21	51	37
14	48	M	5	Mixed	Absent	Eye-gaze + switch with cheek	6	7	6	8	0	21	9
15	53	F	4	Spastic	Present	Hand on screen	5	5	8	7	6	26	5
16	61	F	5	Dyskinetic	Absent	Switch with foot	10	10	10	10	23	53	49
17	70	M	4	Spastic	Absent	Hand on screen	6	8	6	7	4	25	16
18	71	F	4	Spastic	Present	Hand on screen	3	3	6	5	0	14	11

Age: age in months; GMFCS: Gross Motor Function Classification System; Verb. Prod.: Verbal production of ≤ 5 words;
C-BiLLT: Computer-Based Instrument for Low-motor Language Testing; RDLS: Reynell Developmental Language Scales.

Participants

The participants were children without disabilities and children with cerebral palsy. A total of 42 children without disabilities (20 girls, 22 boys; age range 14-60 months) participated. This control group was recruited from mainstream nursery schools and day-care centres. Exclusion criteria were: a) documented history of speech/language delay, b) auditory or visual problems, b) learning disability, and c) any neurological or otherwise chronic disease(s) as reported by parents or nursery school teacher.

There were 18 children with severe CP (9 girls, 9 boys; age range 19-75 months) recruited from rehabilitation centres and special day-care centres throughout the Netherlands. Inclusion criteria were: a) medical diagnosis of CP (i.e. spastic, dyskinetic, ataxic, or mixed), b) severe motor impairment, classified as GMFCS levels IV or V, c) productive spoken vocabulary of less than 5 words, d) no medically diagnosed or otherwise documented history of auditory or visual perception problems, and e) ability to choose between two (familiar) real objects on demand (see below 'discrimination of real objects'). Table 3.1 presents the clinical characteristics and test performances of these children.

The Medical Ethics Committee of the VU University Medical Centre in Amsterdam approved the protocol of the study. All parents of the participants gave their written informed consent.

Procedure

Administration of the C-BiLLT in children without disabilities always took place at the child's own nursery school or day-care centre (in a distraction-free room), and was carried out by a trained speech and language therapist (the first author). Administration of the C-BiLLT in the children with CP took place in their own rehabilitation centre or special day-care centre (n=16), or in the outpatient clinic of our rehabilitation department (n=2). Both direct observation and video-recordings were used to record the performances of the children with CP. To investigate convergent validity of the C-BiLLT, the RDLS was also administered to the children without disabilities and to those with CP who seemed physically able to cooperate. For the latter, the RDLS was not repeated if it had been administered within the past six months (n=5). To avoid potential fatigue issues for the children with CP, the C-BiLLT and the RDLS were administered on different days, with a time interval of at least one week in between. For children without disabilities the RDLS and the C-BiLLT were administered on the same day.

Pretest.

For the children with cerebral palsy, a pretest was administered to establish that these children possessed sufficient cognitive and attentional abilities to perform the tasks included in the C-BiLLT. Parents were asked to bring eight pre-selected objects from the child's home environment ([milk-] bottle or cup, ball, spoon, coat, trousers, toy car, favourite book, digital

video disc [DVD] cover) that were presented in a fixed order of eight pairs. After establishing eye contact, the investigator asked the child *where is your?*, waiting for some sort of reaction from the child. Although the investigator was allowed to stimulate and encourage the child in any way possible, the actual question could only be repeated once. The response was scored correct if the child convincingly (based on Heim, 2001)³¹ fixated his/her eyes on the targeted object for at least two seconds, or reached for the targeted object with his/her arm, foot, elbow, or hand, or pointed to the targeted object with his/her hand, arm, foot, or head, or turned his/her head to the targeted object with an accompanying vocal sound. Children who did not discriminate at least five objects ($n=2$) were excluded from the study.

Scoring

An item was considered completed if the child had (a) pushed an input switch and stopped pushing it for more than 5 seconds, (b) responded with a "yes" or any other vocal expression to the question: *Is this your answer?* (c) pointed to the image on the screen with his/her hand, foot, arm, or elbow, or looked at the image for more than 2 seconds. An item was excluded from scoring if the child pushed the input switch more than 10 times without a clear choice. The investigator stopped the test after eight successive incorrect or excluded responses, or when the child was no longer co-operative or no longer made any visual contact with the flat screen, or had been clearly inattentive. For each Section on the C-BiLLT, correct responses were recorded and summed by the computer.

Data analysis

Performances on the C-BiLLT and the RDLS (first 53 items) was compared both qualitatively and quantitatively. For the qualitative analyses, following C-BiLLT testing, the speech therapists of the children with CP were asked whether their clinical judgment of the child's receptive language ability was in agreement with the test results of the C-BiLLT and whether test results led to any adjustment of the child's individual educational program. For quantitative analyses, the total number of correctly responded items was calculated for both the C-BiLLT (Sections 2 through 5) as well as the RDLS (C-BiLLT and RDLS total scores). Relationships between the dependent measures were analysed by using Pearson's correlation coefficients. Wilcoxon Signed Ranks tests were used to calculate the magnitude of the difference between performances on the two tests. The parallel versions of the items in Sections 1-3 allowed calculation of Cronbach's alpha for these three sections to assess the test's reliability.

Inter-observer and intra-observer reliabilities for direct observation and video recordings (see procedure) of the C-BiLLT were evaluated randomly in the CP group for 255 items (20% of 1256 items scored) distributed over seven children, and were calculated with Cohen's Kappa

and with the intra-class correlation coefficient (ICC) for agreement, respectively (Altman, 1991). For Kappa and ICCs, scores of 0-0.2 were considered poor, 0.2-0.4 as fair, 0.4-0.6 as moderate, 0.6-0.8 as good, and 0.8-1.0 as excellent. Descriptive statistics were used to describe and evaluate differences in performance (co-operation) and pointing strategy (style of response) of the C-BiLLT in the control and CP group, and to describe the responses to the non-linguistic stimuli of the C-BiLLT.

RESULTS

Acceptability

The C-BiLLT was well accepted by the CP group and by children without disabilities. All of the children without disabilities showed an interest in the C-BiLLT test material and reliably responded to many of the presented items. With regard to the experimental set-up, in the children without disabilities, the youngest child to successfully operate the input switches was 16 months old. The youngest participant included (aged 14 months) responded by eye gazing. First successful performance of linear scanning was observed at the age of 25 months. Children not yet capable of mastering linear scanning used direct selection by touching the images on the screen. None of the children aged over 40 months failed to master linear scanning (n=13).

All of the children with CP showed an interest for the C-BiLLT test material and reliably responded to at least some of the presented items. However, one 20-months-old boy with spastic CP (GMFCS V) surpassed the inclusion criteria and learning phases, but failed to respond appropriately to the actual test items resulting in a C-BiLLT total score of zero. In Sections 1 through 4, 11 children with CP applied direct selection (4 used eye gaze; 7 pointed on the screen), 4 used input switches and 3 used a combination of input switch and eye-gazing. Of the 10 children with CP who progressed to Section 5 (linear scanning), 6 (ages range from 29 months to 70 months) showed successful linear scanning. Selection with the input switch was made using hand, arm, or feet. The other children used direct selection by pointing with their hand on the screen (n=4). Table 3.1 presents the different response styles.

Face, Construct and Convergent Validity

For 10 children (54.5%) test results were in agreement with the clinical judgment of the child's speech therapist. For one child, the response mode used for testing was subsequently adopted for the child's AAC device. For two of the children the test score prompted the child's speech therapist to simplify the clinical intervention program; for eight of the children (45.5 %) no earlier reliable test results were available. In some of these children (4), the test results exceeded the clinical judgment of the therapist and confirmed their doubt about the level of the receptive language ability of the child. For the other 4 children the test results reinforced the need for a suitable AAC device.

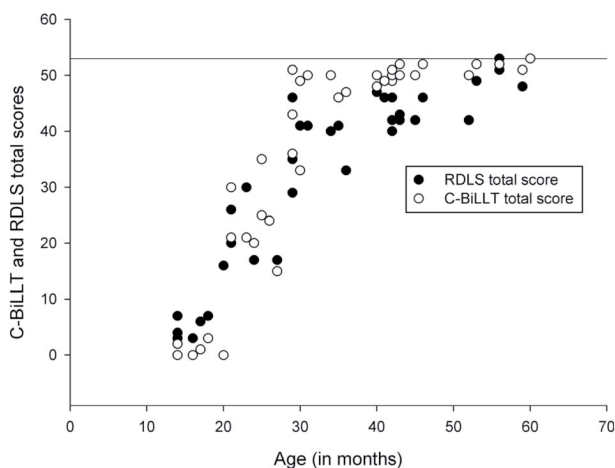


figure 3.4 Individual total scores on both the C-BiLLT and RDLS in children without disabilities.

The correlation between the C-BiLLT total score and the RDLS total score was significant for the children without disabilities ($r = 0.90$, $p < 0.001$), and for the children with CP ($r = 0.84$, $p < 0.001$). The C-BiLLT total scores tended to show a significant difference between children with different types of CP ($\chi^2(df\ 3, N=18) = 5.54$, $p < 0.10$) with the highest scores in children with dyskinetic CP ($n=4$) compared to children with spastic ($n=12$) or mixed CP ($n=2$). C-BiLLT total scores showed no significant differences in children with different GMFCS levels.

Reliability

Sections 1-3 showed a high agreement with their respective parallel versions (Cronbach's alpha = 0.97) for Section 1 and Section 2, 0.93 for Section 3). Inter- and intra-observer agreement was evaluated for the children with CP (Cohen's Kappa = 0.80 and an ICC = 0.92 for inter-and intra-observer agreement, respectively).

Children's Performance

Three children without disabilities (aged 14, 17 and 20 months) responded correctly to the 10 items of Section 1 (accompanied by nonverbal sounds), but failed to respond correctly to the subsequent items that were presented only with verbal instructions, resulting in a total C-BiLLT score of zero. There was a significant positive correlation between age and C-BiLLT performance ($p < 0.001$, $r = 0.93$). The mean total RDLS score in the control group was 32 (SD 16; range 3-53). There was a significant positive correlation between age and RDLS total score ($p < 0.001$, $r = 0.92$). Total scores were significantly higher on the C-BiLLT than on the RDLS for the children without disabilities ($p \leq 0.041$, z -score 2.64) (Figure 3.4).

Of the children with disabilities, 15 (83%) responded correctly to the 10 items of Section 1 (supported by nonverbal sounds), although there was considerable variability in the response.

The mean total score for Part I (Sections 2 through 4) was 16 (SD 9; range 0-30). The overall mean total score (Sections 2 through 5) was 22 (SD 15; range 0-53). Within this same group, 17 children (94%) identified at least some of the nouns and verbs; 13 (72%) identified nouns, verbs, animals and persons. Ten of the children (55%) advanced to the scanning section (part II) and obtained a mean score of 9 (SD 7; range 4-23). These 10 children understood the meaning of a variety of linguistic items such as adjectives (red, small, large), interrogatives, (where, what) and prepositions (in, on, between), embedded in more complex sentence structures. Assessment with the RDLS ended prematurely for all of the children, mainly due to their physical limitations. Four children did not respond at all to the linguistic items of the RDLS, resulting in the standard observational score of 3. The mean overall RDLS total score in the children with CP was 14 (SD 14; range 0-49).

DISCUSSION

The present study aimed to develop the C-BiLLT as a tool to assess comprehension of spoken language in children with complex communication needs and CP by responding to orally presented questions pertaining to visually presented stimuli. Assessment of spoken language can have an impact on both how caregivers and others interact with children and the child's AAC system and education program.

The main results were: a) the C-BiLLT was well accepted by children without disabilities and by children with complex communication needs and CP, b) performance on the C-BiLLT differ widely among the group of children with complex communication needs, c) children with dyskinetic CP obtained higher scores than the children with spastic or mixed CP, d) scores did not differ across children with different GMFCS levels; and e) in children without disabilities there was a strong correlation between the C-BiLLT and RDLS outcome measures.

Acceptability and initial clinical experiences with the C-BiLLT are promising. The fact that most of the children with complex communication needs and CP completed the test, combined with the wide range of scores that was obtained, suggests that the test items held the children's interest and, at the same time, discriminated among differing levels of spoken language comprehension. The experimental set-up of the C-BiLLT allowed even the most severely handicapped children with CP to respond reliably and unambiguously to the tasks. Since many children with severe CP are unable to manipulate objects or point to pictures, in standard language assessment, the investigator must rely on an alternative response to the question and interpret answers; thus it may not be clear whether a failure is due to the child's physical impairment or to limited language skills. One of the advantages of the C-BiLLT is that it allows children with severe physical impairments to use their preferred response method, which permits independent responding without any influence or interference from the investigator. A second advantage is that children seem to benefit from establishing their own "dwell time," particularly those who need considerable processing time before they can

perform the necessary motor actions. A third advantage is that the experimental set-up presents the visual stimuli in a clear contrast. Items are presented with pairs of 262 sets on a 19-inch flat screen. In this way, interpretation of the child's response is clear, even when he or she is using eye gaze. In Sections 1 and 3, the presentation of response items in pairs rather than larger arrays permitted evaluation of the earliest stages of comprehension in both the very young children and children with severe developmental delays (for whom the comprehension of larger arrays may be too difficult). In addition, the parallel section (with repetition of the items in a different order) minimized the risk of misinterpretation and addressed the possibility of 50% correct responding by chance when presenting items in pairs. All of the children with dyskinetic (n=4) and mixed (n=2) cerebral palsy passed linear scanning, whereas the children with spastic cerebral palsy (n=4) used direct selection. Brain lesions are more homogeneous and milder in dyskinetic than in spastic CP, involving mainly the basal ganglia and presenting severe motor impairments

Brain lesions in dyskinetic CP are more homogeneous and milder than in spastic CP, and mainly involve the basal ganglia often with severe motor impairments but less pronounced cognitive deficits. Children with spastic CP, and especially those with severe bilateral spastic CP (GMFCS IV or V), are usually severely retarded in their motor and cognitive development.^{32,33} It has been suggested that scanning techniques require more sophisticated cognitive capabilities (e.g. user attention, short-term memory, developmental level) than direct selection techniques.^{34,35} The present study provides evidence that children without disabilities used direct selection up to the age of 40 months. However, studies on the requirements and effectiveness of various selection techniques in relation to physical demands, rate of communication and cognitive expectations are scarce and more research is needed.^{36,37} Preliminary data on face, construct and convergent validity are promising: C-BiLLT test results were in agreement with or even exceeded clinical judgements, in some cases leading to adjustments in AAC devices and/or revisions of individual education programs. On the other hand, C-BiLLT scores may in other cases overestimate the actual comprehension of spoken language. Therefore, more in-depth psychometric analyses in an extended sample, including children without disabilities, are necessary to establish test reliability more thoroughly.

Nonetheless, the C-BiLLT permitted evaluation of eight children for whom testing had previously not been possible. This reflects the need for an instrument such as the C-BiLLT. The high correlation between the C-BiLLT and the RDLS total score in children without disabilities was expected, since one was based on the other.

The C-BiLLT scores were generally higher than the RDLS scores. The RDLS was administered first, which may explain the higher scores on the C-BiLLT than the RDLS; however, the items of the C-BiLLT did not exactly copy the items of the RDLS, but rather followed the

developmental hierarchy. Moreover, clinical observations confirmed that the children experienced the two instruments as distinct. One explanation for this finding may be that a greater proportion of the items had lower linguistic demands in the C-BiLLT than in the RDLS because the C-BiLLT was constructed for children who generally function at lower levels. Thus, it may be that a higher test score is obtained on the C-BiLLT than on the RDLS for the same level of comprehension. The reason for this greater use of relatively undemanding items was to guarantee small increments of increasing difficulty, thus permitting investigation of differences in comprehension abilities in very young children and/or children with severe intellectual disabilities.

The findings suggest that children with complex communication needs can develop verbal comprehension abilities when productive spoken language is limited. However, considerable variability in verbal comprehension abilities was observed, with higher comprehension scores in children with dyskinetic CP (Table 3.1) which may be expected given the neuropathological basis of their brain disorder. The apparent language advantage in children with dyskinetic CP compared to children with spastic or mixed CP, together with the insignificant correlation between GMFCS levels and performance on the C-BiLLT, suggests that the degree of motor involvement is not predictive of verbal comprehension abilities in children with CP. Although the C-BiLLT shows below normal levels of comprehension in children with severe CP, estimates of language comprehension in these children based on the C-BiLLT, surpassed the clinical impression. Our finding of language development in the absence of normal speech in children with CP is in line with other studies.^{17,21,38-40} However, earlier studies used common standardized language tests with or without adaptations, whereas we developed a new test specifically to enable the opportunity to utilise the child's most suitable mode of response.

An earlier study²³ used a novel method to assess language comprehension in very young children with motor impairments. Linguistic stimuli were presented to nine children with CP (mean age 3.64 years) with videotapes presented in pairs based on the premise that children prefer to watch a video event that matches a linguistic stimulus rather than an event that does not match linguistic stimuli. The children were able to use the linguistic stimuli to motivate their search for the match of a visual event. However, the nature of the discrimination in this paradigm did not guarantee that the children knew the names for both items in a pair. The parallel section of the C-BiLLT ensures a more reliable measurement of a child's comprehension of the names of the items presented in pairs. Other studies have investigated the language skills of only older children or young adolescents with CP.^{17,21,41}

We also found considerable inter-individual differences in children with complex communication needs and CP. Not only verbal comprehension abilities but also abilities to recognize sounds appear to vary across children with complex communication needs and CP. The sound stimuli were presented for 30 seconds but could be stopped as soon as a child responded. Although 30 seconds may seem a rather long viewing time, this was

prompted by clinical impressions that children with CP showed delayed awareness of the sound stimuli. This finding is of particular importance since there is limited experimental work in this area. Processing nonverbal sounds does not require any linguistic knowledge, whereas (depending on the complexity of the speech production) comprehension of spoken language requires recognition of phonological, syntactical, lexical and/or semantic features. Moreover, non-verbal or environmental sounds are considered to convey specific meanings, and the neural circuitry for their recognition may precede the earliest stages of language development.⁴² The impact of exposure to non-linguistic sound stimuli on the development of cognitive and communication abilities of CP children requires further research. Inter- and intra-observer reliability of the C-BiLLT showed excellent scores, however the internal reliability of the instrument has not been properly investigated and needs further investigation in future research.

Limitations of the present study

Analyses of the psychometric qualities of the C-BiLLT would have benefitted from larger groups. Though Cronbach's alpha of the Sections 1-3 and their respective parallel Section showed a high agreement, larger samples, and test-retest results, are needed for proper evaluation of the C-BiLLT as a valid and reliable indicator of a child's true language comprehension abilities. Evaluation of concurrent validity would be stronger if a measure other than the RDLS could be used. Expansion of the sample to include a large cohort of children without disabilities is now underway, as is the use of a larger test battery, that includes the Peabody Picture Vocabulary Test (PPVT-II-NL),⁴³ (translated by Schlichting) for measurement of receptive vocabulary

Children with visual impairments were excluded from the present study. However, because the C-BiLLT images are presented with clear visual contrasts, children with mild to moderate visual impairments should be included in future studies.

Conclusion and recommendations for future research

These preliminary results suggest that the C-BiLLT has the potential to become a useful instrument to assess the comprehension of spoken language in children with complex communication needs and CP. Future research on its psychometric qualities may lead to minor or perhaps major adaptations of the C-BiLLT. When good validity and reliability is achieved, the C-BiLLT can be used to learn more about the development of language comprehension abilities in children with different types of CP, and in children with progressive neurological conditions such as children with progressive white matter disorders.

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Notes

- 1 Registered trademark of Fujitsu-Siemens, headquartered in Munich, Germany.
- 2 Registered trademark of AbleNet Inc., located in Roseville, MN
- 3 Registered trademark of Eastman Kodak Company, with head offices in Rochester, New York.
- 4 Adobe Photoshop is a registered trademark of Adobe Systems Incorporated, San Jose, CA.

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